# An Overview of the DDMA team

Kevin R. Vixie

The Data Driven Modeling and Analysis (DDMA) Team
&
Mathematical Modeling and Analysis (T-7)

Los Alamos National Laboratory

September 28, 2006

# Team History



The team started in 2002

- Essential Component Analysis Proposal: eventually 2 of 3 proposals were funded.
- 2002 Image Analysis Workshop at LANL: high visibility, good attendance
- Initial members: Vixie (lead), Asaki, Wohlberg

Since that time we have grown

- 25 members: roughly half at LANL, half at universities
- Many parallel projects, huge range of expertise
- 2.5M$/year
- Innovative team structure and activities

# DDMA – Data-Driven Modeling and Analysis

## Data analysis requires a synthesis of expertise from many fields.

DDMA


**Lead Team**
Tom Asaki (CCS-2) asaki@lanl.gov
Katharine Chartrand (HPC-4) kncx@lanl.gov
Rick Chartrand (T-7) rickc@lanl.gov
Matt Sottile (CCS-1) matt@lanl.gov
Kevin Vixie (T-7) vixie@lanl.gov

**Team Members**
Bill Allard (Duke)
Erik Bollt (Clarkson)
Patrick Campbell (T-7)
David Caraballo (Georgetown)
John Dennis, Jr. (Rice)
David Dreisigmeyer (HPC-4)
Selim Esedoglu (Michigan)
Gilad Lerman (Minnesota)
Fred Park (Michigan)
Collin Powell (CCS-2)
Bryan Rasmussen (HPC-4)
Paul Rodriguez (T-7)
Pete Schultz (Clarkson)
Valentina Staneva (T-7)
Curt Vogel (Montana State)
Brendt Wohlberg (T-7)
Wotao Yin (Rice)
Mark Abramson (AFIT)
David Arathorn (General Intelligence Corp.)
Chris Orum (D-1)
Robert Sarracino (Scientific Modeling Group, Los Alamos)


**Expertise**
Algorithmics
Computational Science
Analysis
Geometric Measure Theory
Partial Differential Equations
Variational Analysis
Harmonic Analysis
Differential Geometry
Dynamical Systems
Dimension Reduction
Inverse Problems
Numerical Analysis
Optimization
Signal Processing
Statistics
Tomography

**Current Applications**
Algorithm and Prototype Software Development
Comparison Metrics
Dimension Reduction
Extrapolation and Inpainting
Feature Measures
Mixed-Variable Optimization
Object Recognition
Special X-ray Tomography
Warping Transformations
Geometric Image Processing

# Project Areas



- Geometric Analysis
- Image Warping
- Applied Differential Geometry
- Radiographic Inversions
- Object Detection/recognition/segmentation
- Metrics and Regularizations
- Compressed Sensing
- Optimization
- Other areas

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# Team Activities



## External Activities are Considered Critically Important

- Numerous Special Sessions: SIAM Imaging, SIAM Dynamical Systems, AMS meetings and AAAS Annual Meeting
- 2002 LANL Image Analysis Workshop
- 2005 Graduate Summer School at IPAM-UCLA
- RIPS Summer program at IPAM: last 3 years
- Numerous Short Courses and Invited Talks
- DDMA Speaker Series: Over 40 speakers in the first 1.5 years.
- ( ... and half the team is at universities!)

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# Students and Postdocs



Much of the groundwork generated during my GRA in X-division. Postdocs and Students remain key members of the team:

- Current Postdocs: Dreisigmeyer, Rasmussen, Rodriguez
- Current Students: Campbell, Staneva, Powell
- So far, 6 postdocs and 14 students

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# DDMA Working Styles



- We use workshops to develop programmatic deliverables very quickly: 3 day meetings, often 40 hours of work in those 3 days by on the order of 15 members.
- External members are key team members, not simply collaborators on papers. Students are often key contributers, projects are not simply invented and tailored to fit them.
- We convert all classified problems to unclassified analogs and move the problems to any appropriate member of the team, irrespective of clearance level.
- Each team member runs the gamut from intimate contact with raw data to very theoretical investigations.

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# A sampling of the projects



- IDA: an integrated algorithm environment for data analysis
- Sparse X-ray Inversions: Fast and Cheap (and in control)
- Non-convex Regularizations: More from Less
- Using Geometric Measure Theory: Properties of Exact Minimizers
- Metrics that ignore the unimportant: Null-Riemannian Geometry
- Image Warping: Monge-Kantorovich and others
- Random Shapes and Images: important for many reasons
- Object detection and recognition: not just faces

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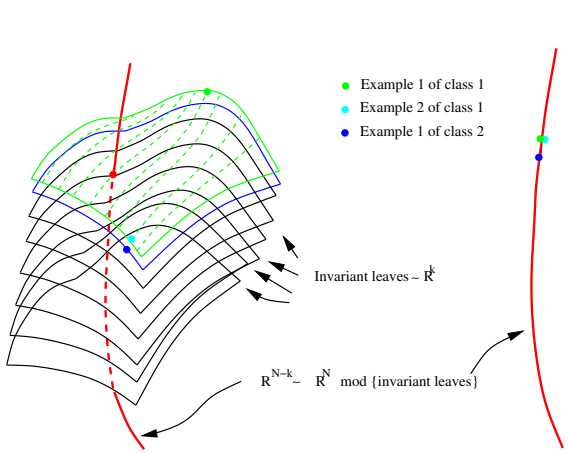
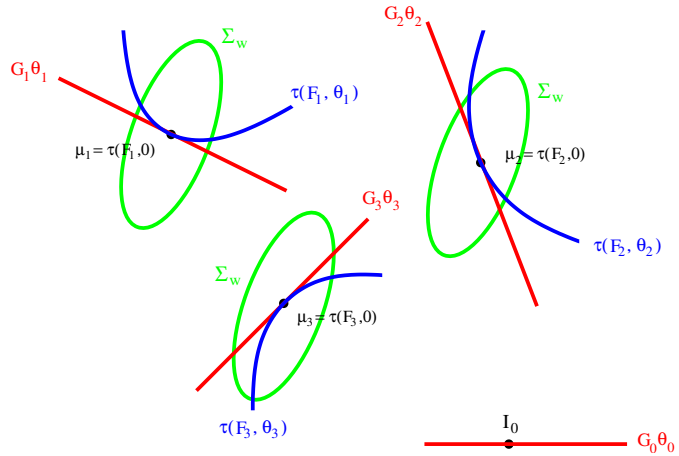
# Classification Mod Invariance: Face Results



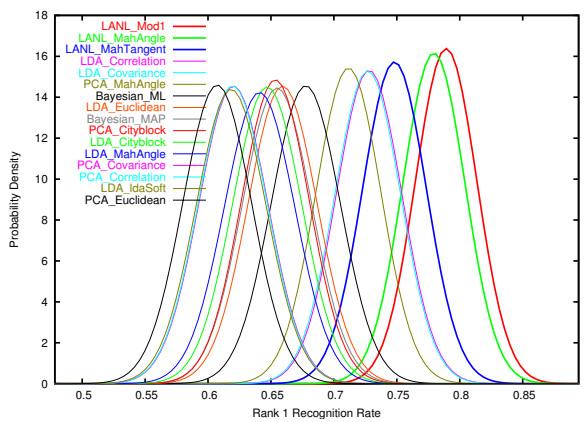
## Early Project: Ignoring differences that don't matter




Factor out the unimportant




Tangent Approximations to Orbits




Results: CSU database ( 2003)

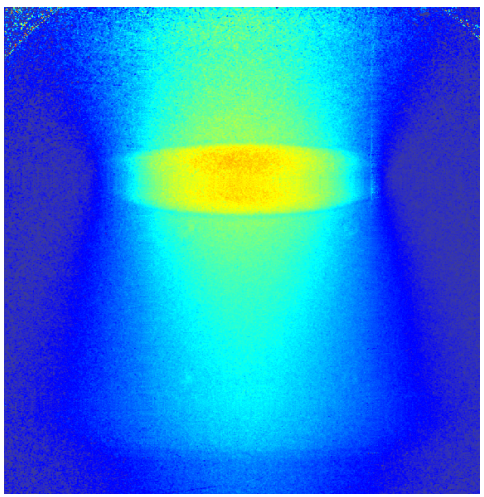
# TVAbel: Inversions assuming symmetry



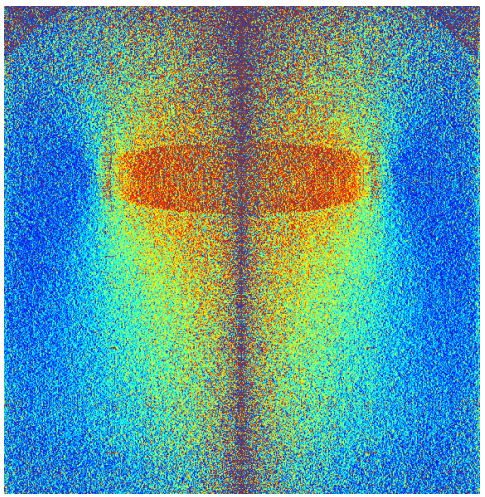
Another of the earliest DDMA projects:

$$\min_{u} F(u) = \int |\nabla u| dx + \lambda \int |Pu - d|^2 dx \qquad (1)$$

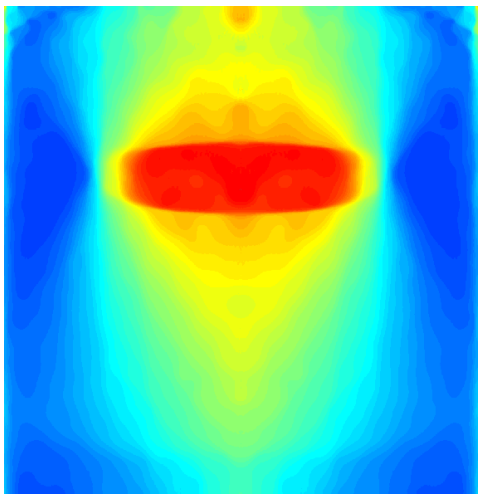
where the $P$ is the measurement operator (Abel projection).



Cropped and Centered Image



Unregularized Abel Inversion



TVAbel Inversion

# IDA:The DDMA Image and Data Analyzer



IDA provides a single framework for executing complex analysis pipelines. It has advantages over plain Matlab:

- Consistent interface for all components, regardless of language.
- Automatic data management via an embedded SQL database.
- Basic visualization capabilities.
- A simple data flow language is provided.
- Built in “parameter study” capability.
- Abstraction of iteration allows for transparent parallel/distributed execution, data-reuse.

IDA makes analysis easier, and allows contributors to rapidly make their components available by conforming to our component standard.

# Member Research: Examples



In the next two slides I show a very short snapshot from a team member's research.

- Wotao Yin was selected because he responded quickly to a request for a synopsis.
- As mentioned above, this is a small slice of the full breadth and depth of the team.

You will hear four of us talk throughout the day about different aspects of our research.

# DDMA Member Research: Wotao Yin (Rice)



- Convex optimization theory and applications, especially the applications of second-order cone programming and semi-definite programming in image processing, statistical learning, and computer vision.
- Extensions of some existing optimization algorithms to sovling problems constrained on smooth manifolds.
- Very recent work includes a fast algorithm for minimizing certain convex functions using the parametric maximum flow algorithm.

# DDMA Member Research: Wotao Yin (Rice)



Using L1TV to remove lighting effects:

Faces under lighting.jpg

Corrected faces